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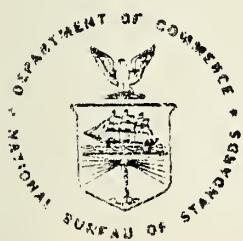
NBSIR 86-3490

Building Technology Project Summaries 1986

Richard N. Wright

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Gaithersburg, MD 20899

November 1986



U.S. DEPARTMENT OF COMMERCE

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**BUILDING TECHNOLOGY PROJECT
SUMMARIES 1986**

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NO. NBS-3490
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**U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director***

ABSTRACT

The Center for Building Technology (CBT) of the National Bureau of Standards (NBS) is the national building research laboratory. It works cooperatively with other organizations, private and public, to improve building practices. It conducts laboratory, field, and analytical research. It develops technologies to predict, measure, and test the performance of building materials, components, systems, and practices. This knowledge is required for responsible and cost-effective decisions in the building process and cannot be obtained through proprietary research and development. CBT provides technologies needed by the building community to achieve the benefits of advanced computation and automation. CBT does not promulgate building standards or regulations, but its technologies are widely used in the building industry and adopted by governmental and private organizations that have standards and codes responsibilities. This report summarizes the projects underway in the Center during 1986.

Keywords: Building research; building technology; criteria; measurement and test methods; performance criteria; project summaries; standards; technical bases

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COMPUTER-INTEGRATED CONSTRUCTION

STANDARDS INTERFACE FOR COMPUTER-AIDED DESIGN

Kent A. Reed, Building Equipment Division, (301) 975-5852

Sponsor: National Bureau of Standards

The objective is to develop the technical principles needed to link computer-usable representations of building codes and standards to computer-aided design systems.

Research on the standards interface for CAD suggests that the generic standards data can be separated from checking and other routines within CAD software systems, leading to greatly improved software reliability and maintainability.

Research involves: (1) data modeling and system interface definition, (2) potential linkages to knowledge-based expert systems, (3) computer processor design and implementation, and experiments with the prototype CAD/standards interface applied to a structural analysis program in order to test the robustness of this approach to the incorporation of standards into CAD and to explore several alternatives that have been proposed for dealing with multi-valued parameters and with implicit contexts.

CONSTRUCTION PROJECT INFORMATION TECHNOLOGIES

Kent A. Reed, Building Equipment Division, (301) 975-5852

Sponsor: National Bureau of Standards

The objective is to provide the technical assistance needed to make the Initial Graphics Exchange Specification fully functional in architecture, engineering, and construction applications. The Initial Graphics Exchange Specification (IGES -- part of ANSI Standard Y14.26M) was developed to support the exchange of product data between computer-aided design (CAD) systems in the manufactured parts industry.

The AEC (architecture, engineering and construction) committee is developing techniques and test cases to measure the correctness and performance of the currently implemented IGES version 2.0 and the new IGES version 3.0 Standards applied to building problems. In addition, the AEG committee is developing technical requirements for future versions of IGES. This activity is particularly important now that the IGES committee is charged with developing the technical basis for an ISO standard.

BUILDING DATA PROTOCOLS

William F. Danner, Building Equipment Division, (301) 975-5855

Sponsor: National Bureau of Standards

The objective is to establish the technical basis for information interchange standards in the building industry.

Rational techniques for describing building practices and the elements of buildings and their properties are needed to establish the technical bases for information interchange standards that will support computer integration of activities in the building process.

Transfer of HVAC-system data between computer-aided design systems using a preliminary protocol will be demonstrated. The HVAC-system case study will be expanded to include multi-faceted information about the components. Additional building elements and systems will be introduced into the preliminary protocol.

DEVELOPMENT OF IGES-CAPABILITY IN THE NAVAL FACILITIES ENGINEERING COMMAND

Mark E. Palmer, Building Equipment Division, (301) 975-5858

Sponsor: Naval Facilities Engineering Command

The objective is to determine the present capability of the AEC industry to interface CAD data digitally, and develop strategies for the Naval Facilities Engineering Command to implement IGES-capability with the same level of performance.

The ability of the AEC industry to exchange CAD data digitally will be assessed through discussions with AEC CAD users and consultants, site visits to major CAD users and reviews of current translator software. The strategies for the implementation of IGES will be designed to address the problems identified and to incorporate the successful procedures which have been developed by current AEC CAD users.

STRUCTURAL ENGINEERING

EARTHQUAKE ENGINEERING

CYCLIC LOADING OF MASONRY BUILDING COMPONENTS

Charles Scribner, Structures Division, (301) 975-6069

Sponsor: National Bureau of Standards

The objective is to develop a rational procedure for determining the ultimate shear strength characteristics of reinforced masonry building shear walls for use in structural design.

A number of failure modes will be examined experimentally to identify the characteristics of each and the significant parameters affecting the different failure modes. Analytical expressions for design as a function of the key parameters will be developed. Key parameters include amount of reinforcement, effect of axial load, effect of aspect ratio, and effect of material properties.

INELASTIC PERFORMANCE OF STEEL-BRACED FRAME CONNECTIONS

John L. Gross, Structures Division, (301) 975-6068

Sponsor: National Bureau of Standards

The objective is to study the gusset plate behavior and the connection of braced elements with column and beam connections in steel frames.

The investigation will involve experimental testings on planar-braced steel frames to be conducted at NBS. The selection of specific variables and specimen design will be coordinated with analytical studies in progress at the University of Arizona. The experimental tests will provide information needed to validate the mathematical models.

LARGE-SCALE BRIDGE COLUMNS SUBJECTED TO REVERSED CYCLIC LOADING

William C. Stone, Structures Division, (301) 975-6075

Sponsors: National Bureau of Standards, National Science Foundation, Federal Highway Administration, California Department of Transportation

The objective is to determine the influence of size (scale factor) on the seismic performance of bridge columns and to provide benchmark full-scale seismic behavior data for bridge columns detailed in accordance with current design criteria.

The test series will consist of one "flexural" specimen, designed to develop high moments at the base of the column with relatively low axial load and shear components, and one "shear" specimen with high lateral load/moment ratio and varying axial loads. Construction details will be those in actual use in order to obtain realistic performance data. A parallel experimental program will obtain seismic performance data for 1/3- and 1/6-scale replicas of the full-scale specimens.

SEISMIC PROBABILISTIC RISK ANALYSIS (PRA) METHODS

Bruce Ellingwood, Structures Division, (301) 975-6049

Sponsor: Nuclear Regulatory Commission

The objective is to examine the validity and limitation of seismic PRA methods by considering how modeling assumptions and uncertain information affect risk estimates, inferences and engineering decisions.

The credibility and sensitivity of PRA risk estimates will be examined with regard to inherent variability, modeling assumptions and uncertainties, and whether certain factors are either omitted from the analysis or not included correctly. The evaluation of PRA methodologies will be kept manageable by focusing on critical systems and components that have been identified as major contributors to seismic risk. The research will emphasize the sensitivity of conclusions drawn from PRA's to assumptions, models and data concerning excitation (seismic hazard and response), and capacity (fragility).

INTERAGENCY COMMITTEE ON SEISMIC SAFETY IN CONSTRUCTION

Charles Yancey, Structures Division, (301) 975-6073

Sponsor: Federal Emergency Management Agency

The objective of the Interagency Committee on Seismic Safety in Construction (ICSSC) is to assist the Federal departments and agencies involved in construction to develop and incorporate earthquake hazards reduction measures in their ongoing programs.

NBS will provide technical and administrative support to the activities of the ICSSC. Specific objectives include:

- o develop seismic design and construction standards for Federal projects,
- o develop guidelines to ensure serviceability following an earthquake of vital facilities constructed or financed by the Federal Government,
- o develop guidelines that provide for independent State and local review of seismic considerations in the construction of critical facilities constructed and financed by the Federal Government where appropriate,
- o develop guidelines for the inclusion of earthquake hazards reduction activities in ongoing Federal programs,
- o develop a strategy to identify existing Federal buildings and other structures that pose unacceptable earthquake-related risks,
- o coordinate the development of guidelines for the consideration of seismic risk in the development of Federal lands.

SEISMIC DESIGN AND CONSTRUCTION PROVISIONS

Edgar V. Leyendecker, Structures Division, (301) 975-6049

Sponsor: Federal Emergency Management Agency

The objective is to support the Building Seismic Safety Council in its effort to support improved seismic design criteria. NBS will provide support as the technical secretariat of the BSSC Trial Design Overview Committee which will be working on resolution of technical issues resulting from the BSSC ballot on the Tentative Provisions described earlier.

It is important that implementation of new research and practical experience be incorporated into design provisions. In order to accomplish this, NBS will work with a panel of experts to identify those advances that are ready for implementation.

NATIONAL EARTHQUAKE ENGINEERING EXPERIMENTAL FACILITY PLANNING STUDY

Charles Scribner, Structures Division, (301) 975-6069

Sponsors: Federal Emergency Management Agency and National Science Foundation

The objective is to define the data needed on full-scale structural behavior; define the type of facility (large shake table, etc.) needed to obtain data; define siting, operational, and cost requirements; assess cost effectiveness with respect to alternative data sources.

The Science Advisor to the President has urged the Federal Emergency Management Agency (FEMA) to initiate the planning study upon which a decision for a national earthquake engineering experimental facility can be based.

A panel of experts and users will be established for the duration of the study to provide advice and guidance. The NBS will conduct a user and research needs study under contract through a series of workshop-like meetings. The NBS, with the advice of the user/expert panel, will prepare a three to five year experimental program with facility requirements. Critical and minimum data needs on full-scale structural performance will be determined.

THREE-DIMENSIONAL BEHAVIOR OF BUILDINGS UNDER SEISMIC LOADING

John L. Gross, Structures Division, (301) 975-6068

William G. Stone, Structures Division, (301) 975-6075

Sponsor: National Bureau of Standards

The objective is to characterize the three-dimensional behavior of building frames subjected to dynamic loadings using color computer graphics to facilitate the presentation, interpretation and comparison of analytical results.

A general purpose finite element analysis code will be used to determine load deformation response, and hysteretic energy absorption capacity of joint details, and to perform dynamic analyses to characterize the behavior of building structures. Predicted behavior will be compared to measured or observed behavior of selected building structures in recent earthquakes or tests.

LOADINGS AND RELIABILITY

CRITERIA FOR STRUCTURAL LOADS AND DESIGN

Bruce Ellingwood, Structures Division, (301) 975-6049

Sponsor: National Bureau of Standards

The objective is to develop criteria for design of buildings that ensure adequate reliability against structural failure and unserviceability and that are appropriate for all construction materials and technologies.

Design standards in the United States rely on different basic approaches to safety checking, depending on the construction material and technology. These different approaches (e.g., ultimate strength design, working stress design) and a failure to consider uncertainties explicitly cause a lack of consistency in reliability and performance, and in some instances, unnecessary design costs.

Structural load data will be analyzed using time series analysis and other statistical techniques to describe stochastically spatial and temporal variation of loads. Realistic limit states for structural systems will be identified from data in the literature and professional experience. Full distribution and advanced first-order, second-moment reliability analysis methods will be used to analyze, in a comparative sense, the reliability of members and simple structural systems. Correlation among loads and among member strengths will be included to determine the extent to which such correlations affect system reliability and performance.

ANALYSIS OF GENERAL COMBINATIONS OF LOADS

Bruce Ellingwood, Structures Division, (301) 975-6049

Sponsor: National Science Foundation

The objective is to develop general approaches for approximating the probability distribution of largest values and other descriptors of individual structural load effects and their combinations.

Existing load combination methods become difficult to apply when three or more loads are acting simultaneously, can examine only linear combinations of independent loads, with a few exceptions, and are generally based on simplistic models developed to capture only load extremes.

The research will examine novel load models (translation processes) that can be obtained from Gaussian processes by nonlinear transformations. These processes will be applied to represent common structural loads. Techniques will be developed for the analysis of linear and nonlinear combinations of independent or dependent translation processes. As a minimum, the project will provide methods for finding the mean rate at which load combinations cross various thresholds and related characteristics that can be applied to analyze ultimate and serviceability limit states. Proposed models will be calibrated to common structural loads based on statistical observations of these loads and to determine probabilistic characteristics of their combined effect.

RELIABILITY OF WOOD STRUCTURES

Erik Hendrickson, Structures Division, (301) 975-6067

Sponsor: National Bureau of Standards

The objective is to develop practical resistance criteria for limit states design of engineered wood structures, taking into account the statistical nature of strength, loads, and creep-rupture behavior.

Structural codes governing the design of engineered wood structures do not as yet include the concepts embodied in probability-based limit-states design. The development of probability-based limit-states design, and the acceptance of probabilistic methods as a basis for setting load and resistance factors.

Statistical descriptions of the strength of wood will be determined using data from the in-grade testing program and from other published sources. The strength analysis must account for the creep-rupture phenomenon that governs failure of wood structures. To this end, computer algorithms are needed to simulate random load process histories for snow, live and wind loads using, as a basis, statistical data gathered in other CBT load research programs.

CHARACTERISTICS OF LOCALIZED WIND LOADS

Richard D. Marshall, Structures Division, (301) 975-6071

Sponsor: National Bureau of Standards

The objective is to provide a basic understanding of the generation of peak cladding loads and instrumentation requirements for their measurement.

Due to the effects of size and shape of the tributary area, location on the building, structure of the oncoming flow, and relative wind direction, the question of codification of cladding loads on low-rise buildings is a very difficult one. Because of the present lack of knowledge of the parent probability distributions of wind pressures, loads and load effects, it is difficult to make reliable predictions of peak values from mean and RMS fluctuating values alone. The bases for most current code provisions that address cladding loads are the results of wind tunnel model studies. Unfortunately, the realities of wind tunnel modeling and testing often require compromises between conflicting requirements with the result that measured peak values tend to be governed by limits on instrumentation frequency response rather than by the physical properties of the flow or of the structural model. To ensure the validity of wind tunnel test results and to establish minimum requirements for instrumentation frequency response, comparisons between model and full-scale test results are required.

CRITERIA FOR DESIGN OF CLADDING SUBJECTED TO WIND LOADS

Emil Simiu, Structures Division, (301) 975-6076

Sponsor: National Bureau of Standards

The objective is to improve the basis for design of cladding subjected to wind loads. Current design criteria for cladding subjected to wind loads are generally recognized to be seriously deficient. The lack of consistency of present criteria results in major economic losses and in safety hazards due to damage to cladding under strong winds. In contrast, uneconomical design of cladding occurs in a large number of situations. Tools from fields of wind engineering, nonlinear mechanics of plates, structural reliability and materials testing will be employed to develop rational criteria for cladding design.

REVIEW OF PROBABILISTIC RISK ASSESSMENTS OF TORNADO MISSILE DAMAGE

Emil Simiu, Structures Division, (301) 975-6076

Sponsor: Nuclear Regulatory Commission

The objective is to assess analyses of risks of tornado missile damage. Among the possible causes of unacceptable behavior of nuclear power plants is the impact of objects, referred to as missiles, whose motion is induced by the action of tornadoes. The Nuclear Regulatory Commission specifies that the probability of occurrence of the event that tornado-borne missiles having critical speeds -7 will hit various nuclear power plant installations does not exceed 10^{-7} in any one year.

The assessment of the verifications will be carried out using probabilistic, statistical, and numerical simulation tools, as well as information concerning frequency of occurrence and physical characteristics of tornadoes, and aerodynamic characteristics and potential number of location of objects susceptible of becoming tornado-borne.

ASSESSMENT OF THE UNCERTAINTIES AND RISKS ASSOCIATED WITH THE DYNAMIC BEHAVIOR OF COMPLIANT OFFSHORE STRUCTURES

Emil Simiu, Structures Division, (301) 975-6076

Sponsor: Minerals Management Service

The objective is to identify failure mechanisms that may result from the dynamic behavior of compliant offshore structures, and apply modern structural reliability techniques to the estimation of nominal failure probabilities of such structures and the assessment of their structural safety.

The behavior of compliant structures in a marine environment is complex. Therefore, the evaluation of their performance can pose difficult problems.

For a number of selected compliant offshore structural types, the study will provide detailed mathematical models of the response that may occur as a result of their dynamic behavior under wind and wave action.

PROBABILISTIC STANDARDS APPROACH FOR FOUNDATIONS

Felix Y. Yokel, Structures Division, (301) 975-6065

Sponsor: National Bureau of Standards

The objective is to develop a technical basis for a probabilistic standards approach for foundations and excavations.

Five standards for foundation and excavation are now being prepared by the ASCE Committee on Foundation and Excavation Standards (CFES). These standards are deterministic and specify safety margins by means of a global safety factor applied to foundations subjected to working loads. This creates a serious compatibility problem with other civil engineering standards. This research explores the technical basis for probabilistic foundation standards.

STRUCTURAL EVALUATION AND BEHAVIOR

NDE METHODS FOR CONCRETE

Nicholas J. Carino, Structures Division, (301) 975-6063

Sponsor: National Bureau of Standards

The objective of this research is to gain a fundamental understanding of the interaction of stress waves with internal discontinuities in concrete structures. Such knowledge is required to develop test methods and proposed standards for using the pulse-echo technique for nondestructive evaluation of the internal condition of existing concrete structures.

Research will evaluate the proposed technique under field conditions and make analytical studies of stress wave interaction with internal defects in bounded structures.

MEASUREMENT OF STRESS WAVES IN CONCRETE

Nicholas J. Carino, Structures Division, (301) 975-6063

Sponsor: Air Force Armament Laboratory, Elgin AFB

The objectives are to develop procedures for the measurement of stress waves in concrete using polymer stress gages, and to study the effect of discontinuities, such as reinforcing steel, on the stress distribution in concrete structures subjected to impact loading.

The research will develop a polymer gage suitable for embedment into fresh concrete and develop suitable experimental techniques.

In order to verify whether the polymer gage gives accurate measurements of the propagating stress pulse, experiments will be performed using mortar specimens.

STRUCTURAL/MECHANICAL DESIGN CRITERIA FOR LOW IMPACT RESISTANT STRUCTURES (LIRS)

Richard D. Marshall, Structures Division, (301) 975-6071

Sponsor: Federal Aviation Administration

The objective is to provide test data and analytical models suitable for the prediction of the response of low impact resistant structures to aircraft impact.

The potential hazard of an aircraft colliding with approach lighting structures during landing or takeoff operations has led FAA to investigate the possibility of developing a structural system with low impact resistance. "Break-away" mechanisms "implemented" in structural systems have been considered by FAA to fulfill the goal. To ensure the effectiveness of such a system (1) investigation of the characteristics of the structural systems, including components such as the electrical conductors, and (2) development of analytical models for the simulation of impact phenomenon are needed.

PUNCHING SHEAR STUDY OF REINFORCED SHELL

H. S. Lew, Structures Division, (301) 975-6060

Sponsors: Minerals Management Service, Chevron Corporation, Mobil Research and Development Corporation, SOHIO Petroleum Company, Exxon Production Research Company

The objective is to develop and verify analytical models for the punching shear resistance of thick, light-weight concrete plates and shells. Concrete offshore structures offer great potential for the safe and economical development of mineral reserves in the Arctic Region. Such structures may experience high concentrated loads from ice with intensities in the range of 100 tons/sq ft. (10MPa). At the present time there are no rational criteria available for the design of thick and heavily reinforced concrete shells, particularly of lightweight concrete subjected to high intensity concentrated loads.

The analytical models will simulate the multi-axial stress states within thick members and will incorporate nonlinear material behavior. Full-scale and model tests will be conducted to verify the analytical model.

TENSILE PROPERTIES OF PLEATED SYNTHETIC ROPE

S. George Fattal, Structures Division, (301) 975-6079

Sponsor: U.S. Army, Aberdeen Proving Ground

The objective of this research is to gain a fundamental understanding of the mechanical properties of synthetic pleated rope. Such knowledge is required to develop field test methods for pulse-type loads and proposed standards and specifications for energy recovery application of mired military vehicles.

At present there is insufficient knowledge on the tensile behavior of pleated nylon rope to serve as basis for developing performance standard for dynamic loading. Initially needed are strength, constitutive properties and energy absorption capacity as influenced by such factors as extreme temperatures, moisture, debris contamination and pulse-type loads. An experimental research project was initiated to study some of these basic properties as influenced by extreme temperature conditions.

BUILDING PHYSICS

ACOUSTICS

ROOM ACOUSTIC MODELING

Simone L. Yaniv, Building Physics Division, (301) 975-5851
Thomas W. Bartel, Building Physics Division, (301) 975-5851

Sponsor: National Bureau of Standards

The objective is to develop improved mathematical predictions of the sound pressure level distribution in rooms from a knowledge of the source(s) characteristics, the properties of the room and its boundaries and from a knowledge of the source location and mounting. A computer simulation model will be developed using numerical and/or finite elements analysis of the wave equation and an algorithm for computing the sound pressure distribution due to a monopole source in a rectilinear room with locally reacting boundaries. The computer simulation will be verified by measuring simultaneously the sound pressure levels in the NBS semi-reverberant laboratory, the sound power output (using the acoustic intensity method), and the sound absorption (using the ensemble averaging technique).

SENSITIVITY ANALYSIS OF INTEGRATED NOISE MODEL

Simone L. Yaniv, Building Physics Division, (301) 975-5851
Daniel R. Flynn, Center for Manufacturing Engineering, (301) 975-6634

Sponsor: Federal Aviation Administration

The objective is to lay the foundation for the revision of the Integrated Noise Model (INM) computer program so as to allow for the generation of confidence limits for each contour generated by the model.

The INM enables the generation of equal noise exposure contours from data on airport altitude and temperature, runway configuration, types and numbers of aircraft, approach and takeoff profiles, airport operational parameters, engine thrust and aircraft noise emission data.

Computer simulation studies will be performed to evaluate the sensitivity of the noise contours generated by the INM model to the following input variables: aircraft noise emission, aircraft altitude profiles, aircraft speed and thrust profiles, aircraft flight tracks and noise attenuation versus distance.

INDOOR AIR QUALITY AND VENTILATION

MICRO-MODELING OF CONTAMINANT CONCENTRATION IN A SPACE

Richard A. Grot, Building Physics Division, (301) 975-6431

Sponsor: National Bureau of Standards

The objective is to develop models for predicting the distribution of contaminants within spaces in buildings.

Many pollutants are released into a space from point sources and the distribution of such pollutants within a space is not uniform. Cooking at a range, hobby activities, smoking, and business machines are examples of such pollutant sources.

Most modeling to date assumes complete mixing in a space or employs a two-compartment assumption with uniformity within each compartment. Therefore, there is need to be able to predict areas where high concentrations will exist.

It is feasible, using first principles, to predict the distribution of contaminants in a space. This information will be used as a basis for developing simplified micro-models which will be verified by experiments within one of CBT's environmental chambers.

A GENERAL INDOOR AIR POLLUTION CONCENTRATION MODEL

George N. Walton, Building Physics Division, (301) 975-6421

James W. Axley, Building Physics Division, (301) 975-6429

Richard N. Grot, Building Physics Division, (301) 975-6431

Sponsors: Department of Energy and Environmental Protection Agency

The objective of this research is to develop a comprehensive validated computer model to simulate dynamic pollutant movement and concentration variations in buildings.

There is need for a general and comprehensive model which can predict the extent, severity, and duration of indoor air pollution. Such a model, when developed, should be useful in the evaluation of various indoor air quality control systems as well as for energy and environmental policy making.

Most of the previous work reported for indoor air pollution modeling is based on a simplistic one-room dilution model which ignores the thermal effects and mixing dynamics.

A model for residences will treat each room in the dwelling as a single well mixed zone. This model will be for multi-zones and contain a detailed and complex description of pollutant concentration rates.

INFILTRATION/VENTILATION -- LARGE BUILDINGS

Richard A. Grot, Building Physics Division, (301) 975-6431
Andrew K. Persily, Building Physics Division, (301) 975-6418

Sponsor: Department of Energy

The objective is to develop test methods for evaluating the movement of air into and within large commercial buildings and to determine the efficiency of the ventilation systems of commercial buildings in providing a mechanism for removing contaminants at a minimum energy cost.

The test methods developed for measuring ventilation efficiency will be applied to two office buildings. Measurements of the distribution of contaminants in these office buildings will also be made. These measurements will produce both a data set on contaminants in office buildings and also an assessment of the concept of ventilation efficiency in characterizing the ability of building ventilation systems to remove contaminants.

EXPERT SYSTEM FOR AIR INFILTRATION PREDICTION AND CONTROL IN BUILDINGS

Andrew K. Persily, Building Physics Division, (301) 975-6418

Sponsor: National Bureau of Standards

The objective is to develop an expert system for air leakage diagnosis and infiltration characterization in residential buildings.

The system is intended to take available information on the building in question and yield its infiltration rates as a function of weather conditions, potential problem areas in terms of heat loss, condensation, and indoor air quality, and appropriate retrofit procedures and their anticipated effects. The system would employ an existing predictive model of air infiltration and a knowledge base consisting of a catalog of building construction details, a database of building components leakage characteristics, and a set of heuristic rules.

REMEDIAL MEASURES FOR REDUCING FORMALDEHYDE EMISSIONS AND CONCENTRATIONS

Samuel Silberstein, Building Physics Division, (301) 975-6420

Sponsor: Consumer Product Safety Commission

The objective of this study is to examine the methods available for reduction of both emission rates and concentrations of formaldehyde. These methods include, but are not limited to, coatings, barriers, air cleaning, formaldehyde removal, air exchange and product/house treatment.

This project will examine methods for formaldehyde concentration reduction; experimentally test and validate those methods which appear most promising and for which insufficient testing has been conducted to allow reasoned evaluation of effectiveness; and identify the most cost-effective, presently available methods for the various expected cases (for example, sources, conditions, etc.) and identify where further research is needed.

CO EMISSIONS FROM DRAFT HOOD EQUIPPED CENTRAL FURNACE

Thomas K. Faison, Building Physics Division, (301) 975-6432

Richard A. Grot, Building Physics Division, (301) 975-6431

Sponsor: Consumer Product Safety Commission

The objective is to determine the effectiveness of prototype, vent safety shutoff system-equipped furnaces in preventing carbon monoxide buildup beyond a safe limit.

NBS will test example furnaces for compliance with requirements of the proposed ANSI Z21.47G standard (Section 2.8 Combustion and Section 2.18 Vent Safety Shutoff System). NBS will develop a model based on interroom air flows for predicting the levels of CO in various parts of the house due to failure of proper operation of the venting system. Spillage of CO will be simulated as the result of (a) continued operation with a partially blocked vent, and (b) cyclic operation with maximum "on" time without triggering the spill switch. The model, based upon measurements in the mock-up, will be used to predict the CO levels in actual houses due to spillage for draft hoods.

LIGHTING

CEL-1 LIGHTING PROGRAM

Stephen J. Treado, Building Physics Division, (301) 975-6444

Sponsor: Naval Civil Engineering Laboratory

The objective is to support and maintain the CEL-1 lighting computer program and to use it in conjunction with the BLAST program to evaluate the impact of various fenestration options on visual performance, building thermal and lighting loads, and building energy consumption, leading to development and improvement of design.

A hybrid version of BLAST/CEL-1 has been developed to allow the simulation of building energy performance, including lighting system performance and the effects of daylighting. In order to enable the development of design guidelines for effective fenestration use in buildings, the sensitivity of building energy usage to fenestration design must be evaluated as a function of other building parameters. Based on this analysis, design guidelines for fenestration and lighting strategies will be developed based on the simulation results for various locations.

DAYLIGHTING STUDIES

Stephen J. Treado, Building Physics Division, (301) 975-6444

Sponsor: National Bureau of Standards

The objective is to evaluate the impact of daylighting on building energy requirements, visual performance and lighting system effectiveness, to enable development of design guidelines and procedures for the optimum utilization of daylight in buildings.

An expert system for daylighting design and analysis will be developed incorporating the following elements:

- a) detailed sky and solar model,
- b) fenestration daylight characteristics,
- c) detailed interior light flux distribution,
- d) surface luminance distribution,
- e) glare conditions,
- f) task visibility,
- g) fenestration design optimizer.

Leading experts in the area of windows and daylighting will be consulted regarding the judgment-based portion of the expert system.

LIGHTING GEOMETRY AND CONTRAST MEASUREMENT

James A. Worthy, Building Physics Division, (301) 975-6446

Sponsor: National Bureau of Standards

The objective is to develop a technique for measuring black-white contrasts in complex situations.

It is generally understood that contrast is the stimulus for vision. No method exists, however, for measuring contrast in realistically complicated scenes. Since the eye probably makes some use of every edge, highlight and texture available to it, a realistic contrast meter should in some way "see" these features. The research explores development of a spatial frequency metric for the overall contrast in a scene.

ILLUMINATION MODEL - COLOR

Gerald L. Howett, Building Physics Division, (301) 975-6447

Belinda L. Collins, Building Physics Division, (301) 975-6456

Sponsor: National Bureau of Standards

The objective is to develop color appearance formulas which can be used to predict the interaction of light source and surface color in interior spaces for inclusion in the comprehensive illumination model.

A color-appearance formula is highly specific; it predicts what a sample with a given reflectance spectrum (color) will look like when it is illuminated by a source with a given spectral power distribution to which the observer is adapted. To develop a predictive formula requires experimental assessment of color appearance under different, commonly used sources; determination of the appropriate mathematical formula; and validation of the formula.

DISCRIMINABILITY OF FEATURES OF SECURE DOCUMENTS

Belinda L. Collins, Building Physics Division, (301) 975-6456

Sponsor: Bureau of Engraving and Printing, Department of Treasury

The objective of this project is an assessment of those features of existing and proposed secure documents that appear effective in deterring counterfeiting. Detailed determination will be made experimentally of those features, such as color, line quality, design content, security devices, etc., as well as lighting conditions, which can be effective in ensuring the noticeability of secure documents.

INTERACTION BETWEEN LIGHTING AND HVAC SYSTEMS

Stephen J. Treado, Building Physics Division, (301) 975-6444

Sponsors: Department of Energy and Electric Power Research Institute

The objectives are to obtain the heat distribution characteristics of various lighting systems in typical room thermal environments, to develop a database for detailed lighting heat transfer calculations, to analyze the components of lighting heat transfer, to evaluate the influence of wall and floor construction and HVAC design on lighting and cooling/heating loads, and to develop and validate a computer model for simulating the interaction between lighting and HVAC systems. The initial activity will result in construction of the lighting test facility. A preliminary model also will be developed prior to the related measurement phase of the project, and used to evaluate the potential variation of parameters for the measurements. The model will be validated using measurement results, and improved accordingly.

THERMAL ANALYSIS

THERMAL MODELING OF BUILDINGS

George N. Walton, Building Physics Division, (301) 975-6421
Jin B. Fang, Building Physics Division, (301) 975-6417

Sponsor: National Bureau of Standards

The objective is to develop modern modeling techniques for predicting air movement and heat transfer in multi-room buildings and complex geometrics.

NBS has developed the Thermal Analysis Research Program (TARP) which can predict the interzone heat transfer and interzone movement of air, moisture and contaminants. The research effort on thermal modeling will be directed at the development of accurate and efficient models for predicting radiative energy exchange both around a building and the building interior and also incorporation of modern computer methods such as adaptive computer language structures into building energy models. The algorithm development for radiative energy exchange will include methods for calculating view factor, shadowing calculations and reflective radiative energy both diffuse and specular. Research also will give theoretical bases to the modular structure of thermal analysis simulation so that modern computer methods, such as adaptive computer language, can be applied to the major general elements of thermal simulation: formation of component response, description of the environmental driving forces, assembly of the model equations, solution methods for solving the equations and evaluation of the system dependent quantities.

MATHEMATICAL MODEL FOR COMBINED FLOW OF HEAT AND MOISTURE

Douglas M. Burch, Building Physics Division, (301) 975-6433
Thomas K. Faison, Building Physics Division, (301) 975-6432

Sponsor: National Bureau of Standards

The objective of this research is to develop a mathematical model to predict the combined flow of heat and moisture through multi-layered retrofitted walls of residences. This model will be validated through a series of laboratory experiments, and the effect of moisture accumulation on the overall thermal resistance will be investigated.

A model for predicting the heat and mass transfer in wood during a kiln drying process has recently been developed and validated at the Washington State University. The model includes liquid transport via capillary action as well as diffusion. The present study will extend this model to include layers of insulation and interior wall surface in addition to an exterior wood surface. The formulation will include the effect of vapor resistance offered by paint layers at interior and exterior surfaces.

SIMPLIFIED MODEL -- SPACE COOLING LOADS

Douglas M. Burch, Building Physics Division, (301) 975-6433

Sponsor: Department of Energy, Oak Ridge National Laboratory

The objective of this study is to investigate the feasibility of using the Sander and Barakat theory to develop a simplified mathematical model for predicting weekly space loads of a residence.

The Thermal Analysis Research Program (TARP) will be used to predict weekly space cooling loads for simulated, insulated and uninsulated wood-frame residences located in the Washington, DC., area. These predictions will be used to develop a simplified model of solar heat gain using the Sander and Barakat model. The simplified model will be used to predict solar heat gain of six test buildings and comparisons will be made with existing thermal data.

ENERGY PERFORMANCE OF ATRIA

Stephen J. Treado, Building Physics Division, (301) 975-6444

Sponsor: Department of Energy

The objective is to evaluate the energy performance of large glazed building atria, including thermal and daylighting effects, as related to fenestration design, to enable development of design guidelines.

The design of atria exerts a significant influence on building energy requirements and performance. Information is needed regarding the heat transfer mechanisms in atria, the daylighting performance and the energy impact of atria on the overall building.

Measurements will be made in two atria. The data compiled in the measurement portion of the work will be used to determine the most effective and accurate modeling procedures for the computer simulation, such as the number of sub-zones needed to model the atrium and adjoining spaces and the magnitude of any temperature stratification effects.

VARIABLE AREA HEAT FLUX AND EDGE EFFECTS FOR GUARDED HOT PLATE APPARATUS

Brian G. Rennex, Building Physics Division, (301) 975-6434

Sponsor: National Bureau of Standards

The objectives are (1) to develop a new test method to determine relative values of thermal resistance for typical metered areas so that the stated values of thermal resistance accurately reflect the variable nature of the material evaluated, and (2) to calculate the edge effect for square geometry heat flow meter apparatuses and make experimental measurements to validate the theory.

NBS provides calibration specimens for the measurement of thermal resistance to users throughout the country. Two important factors in the characterization of a particular calibration are the size of the user's metered area and the thickness at which the user operates. Because the insulation material tested can be highly variable over the metered area, it is important to have a test method to compare thermal resistance values for various meter-area sizes. The other factor is the uncertainty at large thicknesses. This uncertainty is poorly understood because there is almost nothing in the literature to quantify it.

LOW-K STANDARD REFERENCE MATERIAL

Brian G. Rennex, Building Physics Division, (301) 975-6434

Sponsor: Department of Energy, Oak Ridge National Laboratory

The objective is to establish a thermal standard reference material (SRM) having a low thermal conductivity that will be applicable for use over an extended temperature range.

As better insulating materials are developed in response to energy conservation programs and products are streamlined so that less material is used, the need has been identified for a new standard reference material that has a low thermal conductivity. Materials having high thermal resistance values require special measurement considerations for accurate determination of thermal properties. A low-K SRM is needed for use in calibration of instruments and as a base for comparison of thermal property measurements -- to facilitate research and development of more effective insulating materials.

The properties of selected fumed silica products will be evaluated and a candidate selected for more comprehensive characterization. A report will be prepared to establish fumed silica as a standard reference material.

EXPERIMENTAL EVALUATION OF DYNAMIC TEST PROCEDURES

Douglas M. Burch, Building Physics Division, (301) 975-6433

Sponsor: Department of Energy, Oak Ridge National Laboratory

The objective is to experimentally investigate three dynamic temperature profiles for calibrated hot boxes to determine the transient heat-transfer characteristics of exterior walls, using solar diurnal temperature cycles, sinusoidal waveforms at three different frequencies, and a triangular-shaped pulse. The research will define the type of thermal performance data needed in design and lead to development of practical test methods for acquiring the data. The research also will provide engineering design data on wall systems that have potential for significant energy savings.

THERMAL MASS EFFECT ON RESIDENTIAL COOLING AND HEATING

Douglas M. Burch, Building Physics Division, (301) 975-6433

Sponsor: Electric Power Research Institute

The objective is to analyze previously measured test results of the NBS thermal mass test buildings in order to investigate the effect of building envelope and building operation parameters on reducing and delaying peak space heating/cooling loads. The study will investigate the effect of the thermal mass of the interior partition walls and interior furnishings on reducing and delaying peak summer cooling loads. The study also will compare space heating/cooling loads predicted with EMPS and TARP computer programs to corresponding measured heating/cooling loads.

BUILDING ENVELOPE THERMAL ANOMALIES

Richard A. Grot, Building Physics Division, (301) 975-6431

Sponsor: Department of Energy

The objective is to develop in-situ test methods for quantifying the heat losses due to thermal anomalies and thermal bridges in building insulation systems.

Thermal anomalies exist in building insulation systems due to improperly installed insulation, convective air movement in the insulation and moisture damage to the insulation. As buildings become more insulated, the heat loss due to penetration of structural members becomes proportionally more significant and can degrade the performance of the insulation system by about 10 to 20 percent. These parts of the structure are also points at which condensation can occur and thus become potential sources of building deterioration. Current analysis and models of the building envelope ignore the presence of thermal bridges and anomalies. At present there is no method for quantifying the heat loss due to these effects so that the impact of correcting the anomalies or bridges cannot be accurately projected.

EVALUATION OF APERTURE GLAZING MATERIALS

Michael E. McCabe, Building Physics Division, (301) 975-6422

Sponsor: Department of Energy

The objective is to evaluate a simple, comparative test method for measuring thermal performance of alternative window glazings under field conditions.

The thermal performance of windows has been found to have greater sensitivity to climatic variables, such as air temperature, solar irradiance and wind velocity, than anticipated based on ASHRAE Handbook data. However, window manufacturer's performance data based on testing done at extreme design conditions under laboratory conditions may not be directly applicable for estimating energy performance over a heating and/or cooling season. These concerns suggest the need for development and evaluation of other window test methods. The research will evaluate thermal performance by long-term, side-by-side testing of competing window designs in the field using portable calorimeters.

THERMAL PERFORMANCE OF FENESTRATION SYSTEMS

Michael E. McCabe, Building Physics Division, (301) 975-6422

Sponsor: Department of Energy

The objectives are to measure the rate of heat transfer in three window systems under laboratory conditions and to assist in development of standard laboratory methods for measuring the fenestration thermal performance values to be used in calculating building energy requirements.

A number of different laboratory procedures for testing of building thermal envelope components are available; however, no consensus currently exists as to which procedure is most suitable for measuring the U-value of fenestration systems. A standard procedure is needed for measuring and reporting the U-value of fenestration systems that is sensitive to variations in climatic conditions. The research will develop and validate a standard laboratory test procedure for measuring the U-value of fenestration systems.

DATA FOR RESIDENTIAL ENERGY CONSERVATION STANDARDS

Frank J. Powell, Building Physics Division, (301) 975-6454

Sponsor: Department of Energy, Battelle Pacific Northwest Laboratories

The objective is to provide technical support to the energy standards program by preparing a report that will summarize and evaluate the state-of-the-art in regard to thermal mass, advanced thermal insulation materials and systems, and the effects of moisture, air movement and gaps or cavities on insulated structures. These data will provide technical bases for residential energy conservation standards.

IN-SITU TEST METHOD -- UNDERGROUND DISTRIBUTION SYSTEM

Jin B. Fang, Building Physics Division, (301) 975-6417

Sponsor: Department of Energy

The objective is to develop in-situ methods for measuring the heat losses from various underground insulated piping systems in district heating and cooling.

An automated, microcomputer controlled instrument and data acquisition system will be developed and constructed for measuring soil thermal conductivity and continuous monitoring of earth temperatures along with surface heat fluxes. The thermal probe technique being developed at NBS will be used for in-situ measurements of the heat losses and heat gains from selected underground systems.

EVALUATION OF UNDERGROUND HEAT DISTRIBUTION SYSTEMS

Jin B. Fang, Building Physics Division, (301) 975-6417

Sponsor: Tri-Services

The objective is to develop methods for predicting and measuring the heat loss from the underground heat distribution systems and to provide technical assistance to the Tri-Service Committee on Underground Systems for the Implementation of Criteria for Underground Heat Distribution Systems.

The research will use the automated microcomputer controlled data acquisition system being developed at NBS for the measurement of the heat loss from underground heat distribution systems; conduct the heat loss measurement of underground systems at Fort Jackson, SC., where a separate calorimetric measurement will be performed; and perform computer simulation calculations using the finite element method on shallow trench underground systems and compare the predicted results with the experimental data from the field data.

BUILDING EQUIPMENT

MECHANICAL SYSTEMS AND CONTROLS

SYSTEMS AND CONTROLS LABORATORY AND INTEGRATED BUILDING SERVICES

George E. Kelly, Building Equipment Division, (301) 975-5870

Sponsor: National Bureau of Standards

The objective is to carry out fundamental and applied research on building controls, building system dynamics, adaptive optimization algorithms and integrated building services.

Such information will greatly improve the reliability of building systems and controls, reduce maintenance requirements, and provide better services at lower first costs.

The research in FY 86 will involve studying the performance of whole building systems using HVACSIM+ and the NBS Administration Building, evaluating building control algorithms that involve dynamic interactions between the building shell, the HVAC system and controls, exploring the use of real time building system models for optimizing whole building performance (i.e., a model reference approach to adaptive control), and developing procedures and test methods for evaluating the performance of HVAC systems and controls in actual buildings.

BUILDING/HVAC/CONTROLS DYNAMIC MODELING

George E. Kelly, Building Equipment Division, (301) 975-5870

Sponsor: Department of Energy

The objective is to develop and verify building system models and a simulation program for evaluating the dynamic interactions among the building shell, the HVAC system and controls.

None of the currently used building simulation programs (e.g., BLAST 2, DOE 2) account for HVAC/control dynamics. As a result of this, there is very little reliable data on the amount of energy waste in buildings due to control dynamics and absolutely no information on how to design and operate building control systems to optimize dynamic performance.

Data on the performance of the 11-story NBS Administration Building will be used to verify and refine the building shell portion of HVACSIM+ and the verified program employed to study the dynamic performance of whole building systems.

EMCS ALGORITHM

George E. Kelly, Building Equipment Division, (301) 975-5870

Sponsors: Department of Energy and Department of the Navy

The objective is to develop and verify public domain algorithms and to assist the Navy in developing the equipment and procedures for testing the performance of Energy Management and Control Systems (EMCS).

The work includes (1) developing and verifying public domain algorithms for typical HVAC/building applications, and (2) assisting the Navy in developing an EMCS Testing Device and Evaluation Procedure for determining the performance of Energy Management and Control Systems in factory tests or acceptance tests in the field.

KNOWLEDGE-BASED INPUT GENERATION PROGRAM FOR BUILDING SYSTEM SIMULATION PROGRAM

Stanley T. Liu, Building Equipment Division, (301) 975-5880

Sponsor: National Bureau of Standards

The objective is to develop an intelligent front-end program for building system simulation programs utilizing knowledge-based programming techniques.

It is very difficult to set up a model of a particular building system to be simulated. The user is required to have extensive knowledge, not only of the system and equipment to simulate, but also of how the simulation programs actually work, and all the inputs, outputs, and parameters used by the models.

The front-end program will take over most of the tasks required of a user in the tedious inputs, outputs, assignment of indices to the inputs and outputs, and tracing and index matching among connected component modules.

INSPECTION AND TESTING PROCEDURES FOR COMMISSIONING HVAC EQUIPMENT AND SYSTEMS

James Y. Kao, Building Equipment Division, (301) 975-5871

Sponsor: General Services Administration

The objective is to develop comprehensive inspection and testing procedures for commissioning of HVAC equipment and systems in Federal buildings.

The performance of the building subsystems and their energy consumption are contingent upon the subsystems being installed, adjusted, and operated according to the intention of the designers.

NBS will develop recommended inspection procedures for commissioning HVAC equipment and systems; and measurement methods and test procedures for the type of equipment and systems.

THERMAL MACHINERY

NONAZEOTROPIC REFRIGERANT MIXTURE PROPERTY EVALUATIONS

David A. Didion, Building Equipment Division, (301) 975-5881

Sponsor: National Bureau of Standards

The objective is to determine the values of the thermodynamic and transport properties of nonazeotropic refrigerant mixtures to the degree of accuracy and precision necessary for the evaluation of the impact these mixtures may have on the refrigeration cycles.

In recent years, interest in the use of nonazeotropic binary mixtures as a working fluid for refrigeration systems has increased greatly. It does not appear that new single component refrigerants can be developed because of the limited number of elements available for combination to produce volatile, nonflammable, nonpoisonous, chemically stable compounds.

The future of nonazeotropic mixtures in the refrigeration industry for the most part depends upon creation of new types of refrigeration cycles. Conceptually, there exists a myriad of cycles with refrigerant mixtures that appear superior to the existing single component refrigerant cycle. In order to conduct a quantitative evaluation and determining trade-offs or economic benefits, it is necessary to have the property values of a variety of mixtures as well as an understanding of how mixture properties may vary under different operating conditions.

MEASUREMENTS OF MODIFIED HP CYCLES USING NONAZEOTROPIC MIXTURES

David A. Didion, Building Equipment Division, (301) 975-5881

Sponsor: Department of Energy, Oak Ridge National Laboratory

The objective is to experimentally evaluate in the laboratory the thermodynamic and operational behavior of modified heat pump cycles using nonazeotropic refrigerant mixtures.

A heat pump model for nonazeotropic mixtures has been developed by NBS under EPRI sponsorship which uses a new hard-sphere equation-of-state. The new model will be verified through comparisons with data obtained on a new "bread-board" heat pump built in the NBS laboratory, and then used to supplement the experimental data.

EXAMINATION OF NONAZEOTROPIC MIXTURE REFRIGERANTS FOR HEAT PUMPS

David A. Didion, Building Equipment Division, (301) 975-5881

Sponsor: Electric Power Research Institute

The objective of this study is to develop a simulation model of a vapor compression cycle operating with binary nonazeotropic refrigerant mixtures and to perform a parametric evaluation of the energy performance advantages of these mixtures for heat pumps.

The study will include thermodynamic modeling of refrigerant mixtures, heat transfer modeling of heat pump cycles, a parametric study of the nonazeotropic mixture advantages in a heat pump cycle, and examination of the ideal refrigeration cycle's potential advantages when using nonazeotropic mixtures.

FURNACES, BOILERS AND HOUSEHOLD HEATER TEST PROCEDURES

Esher R. Kweller, Building Equipment Division, (301) 975-5861

Sponsor: Department of Energy

The objectives are to provide the industry, via DoE, an equitable testing and rating procedure for determining the seasonal energy performance of central residential furnaces, boilers, and household heating equipment and to assist DoE in this effort by conducting laboratory studies of furnaces, boilers, and household heaters and their associated equipment.

Current work includes: (1) investigation of cyclic rates and cyclic controllers; (2) evaluation of the part load efficiency of combination space heating/water heating furnaces and boilers; (3) test procedures for furnaces and boilers equipped with vent dampers; and (4) test procedures for catalytic heaters and high efficiency condensing type gas-fueled space heaters.

HEAT PUMP AND AIR CONDITIONER TEST PROCEDURES

David A. Didion, Building Equipment Division, (301) 975-5881

Sponsor: Department of Energy

The objective is to provide industry, via DoE, with an equitable testing and rating procedure for determining the seasonal energy performance of central residential air conditioners and heat pumps.

Neither the current government or industrial procedures addresses the case where the components of a given system are manufactured by different companies and assembled in the field (e.g., replacement outdoor unit with old indoor coil intact or new installations with indoor and outdoor units from different manufacturers).

A computer simulation model for determining the capacity of a finned-tube, direct-expansion coil will be developed and verified. An experimental methodology will be developed to evaluate the ratio of the mass rate of flow of the mixed coils expansion device to the matched coils expansion device. The current recommended procedure for mixed-matched air conditioners will be extended to include heat pumps in the heating mode.

REFRIGERATORS, REFRIGERATOR-FREEZERS AND FREEZERS

Robert A. Wise, Building Equipment Division, (301) 975-5863

Sponsor: Department of Energy

The objective is to provide support to DoE in the development and modification of test procedures for refrigerators, refrigerator-freezers, and freezers (R-F) as delineated in the Energy Policy and Conservation Act (EPCA) and as amended by the National Energy Policy and Conservation Act (NEPCA).

NBS will develop an automated, interactive, and adaptive testing system for R-F environmental chamber testing, and provide DoE with a proposed amended test procedure that will allow testing of R-F units that incorporate adaptive defrost controls (ADC).

WATER HEATER TEST PROCEDURES

James E. Harris, Building Equipment Division, (301) 975-5863

Sponsor: Department of Energy

The objective is to expand and/or modify the DoE water heater test procedures where required and to provide laboratory data, analyses and recommendations related to the test procedures.

NBS will conduct laboratory tests of gas, oil, electric storage type water heaters using the simulated use test method. The effect of variable daily hot water usage and variable standby loss on the energy factor will be studied. Testing will be completed of combination water heater/space heater as a water heater in order to develop a test method for this combination appliance. Testing will be completed of an "indirect" water heater using a gas-fired instantaneous water heater to assess the potential for energy savings with this type of a system.

CONSULTATION/TECHNICAL SUPPORT

Robert A. Wise, Building Equipment Division, (301) 975-5863

Sponsor: Department of Energy

The objective is to provide support to DoE in the modification of test procedures for household appliances as delineated in the Energy Policy and Conservation Act (EPCA) and as amended by the National Energy Policy and Conservation Act (NEPCA).

NBS will review material received from petitioners for test procedure waivers to determine if a reasonable case for technical validity is offered to justify the waiver. Information will be analyzed and technical data received by DoE from petitioners for test procedure waivers, from other industry or interested persons, and rebuttal responses relating to requests for waivers. NBS will provide DoE with an evaluation of test procedures or procedure changes proposed by industry, trade associations, engineering societies, or consumer groups.

SOLAR EQUIPMENT

INVESTIGATION OF SOLAR HOT WATER DESIGN STRATEGIES

A. Hunter Fanney, Building Equipment Division, (301) 975-5864

Sponsor: Department of Energy

The objective is to demonstrate and quantify the improvement in the thermal performance of direct-forced circulation solar energy systems that can be obtained with stratification enhancing return tubes.

The thermal performance of solar domestic hot water (SDHW) systems is influenced by the rate at which heat transfer fluids within the systems are circulated.

Experiments will be conducted to determine if the use of a lower flow rate will further improve the performance of a solar hot water system equipped with a stratification enhancing return tube.

A CORRELATION PROCEDURE FOR THERMOSYPHON SOLAR SYSTEMS

A. Hunter Fanney, Building Equipment Division, (301) 975-5864

Sponsor: Department of Energy

The objective is to develop a correlation procedure for thermosyphon solar hot water systems which would allow the prediction of long-term performance from short-term thermal measurements.

According to the Solar Rating and Certification Corporation (SRCC), thermosyphon systems currently hold the largest share of the solar domestic hot water (SDHW) market.

It is planned to develop a correlation for thermosyphon systems which would allow one to predict the monthly performance of a thermosyphon SDHW system using the results of the SRCC system rating test in conjunction with historical meteorological data.

A RATING PROCEDURE FOR INTEGRATED COLLECTOR STORAGE SYSTEMS

A. Hunter Fanney, Building Equipment Division, (301) 975-5864

Sponsor: Department of Energy

The objective is to develop a rating procedure for integrated collector storage solar hot water systems.

Solar industry organizations have stated that a rating procedure is needed for integrated collector storage systems.

The study will: conduct short-term tests using an integrated collector storage system and correlate test results to meteorological conditions which existed during the tests; collect high-quality, long-term experimental data for a typical integrated collector storage system; and develop a technique to correlate the long-term experimental data to the meteorological conditions which existed during the outdoor tests.

DETERMINATION OF INTERZONAL HEAT TRANSFER DISCHARGE COEFFICIENTS

Bal M. Mahajan, Building Equipment Division, (301) 975-5857

Sponsor: Department of Energy

The objective is to determine the discharge coefficients for typical interzonal air-flow openings.

The need for accurate simulation of heat and mass transfer in buildings has been identified in both the DoE Passive Solar Commercial Buildings Program and the DoE Manufactured Buildings Program.

Data acquired at the NBS Passive Test Facility during FY 85 indicated poor agreement between measured air flow data and values predicted by interzonal air-flow algorithms.

In FY 86 discharge coefficients will be determined for various sizes and locations of the openings interconnecting two zones.

PLUMBING

EVALUATION GUIDELINES FOR COMPUTER DRAINAGE SYSTEM DESIGN PROCEDURES

Lawrence S. Galowin, Building Equipment Division, (301) 975-5865

Sponsor: National Bureau of Standards

The objective is to develop hydraulic parameters and waste transport requirements in partially filled drainage pipe systems suitable for evaluating computer design methods.

Computerized design procedures are now available which are based on solving the governing equations for flow in the drainage system. There is need for a reference source of multiple loading patterns and associated measured results in a representative drainage network to provide the basis for evaluating computer design programs by codes, standards and local jurisdictional officials.

Based on prior experimental studies at NBS and Brunel University, NBS will provide a set of loading patterns with measured results for comparisons with predictive models. Data will be developed for: (a) vertical drain stack annular thickness as a function of steady flow rates, pipe diameters and wall roughnesses; (b) horizontal pitched drain normal depths as a function of pitch, diameter and wall roughness in steady flow; and (c) time dependent surge flow depths and flow rates as a function of pipe pitches, diameters and wall roughnesses. Considerations for the ranges of agreement between computations and test results and recommendations to guide users will be prepared.

EFFICIENT DRAINAGE SYSTEM DESIGN

Lawrence S. Galowin, Building Equipment Division, (301) 975-5865

Sponsor: Tri-Services

The objective is to develop a detailed innovative building drainage pipe system design as an alternative to conventionally designed plumbing code-based drainage systems.

The half-filled depth requirement in current plumbing codes does not consider the surge and attenuation phenomena and hence does not allow for effective use of the drain pipe load carrying capability. Accurate predictions of the time varying depths from the new computer model can be adjusted to provide the "safety factors" for design and then used for sizing the drainage system.

RESIDENCE TIMES IN FLOW SEPARATION - WATER MAINS

Lawrence S. Galowin, Building Equipment Division, (301) 975-5865

Sponsor: Environmental Protection Agency

The objective is to evaluate flow separate conditions and eddy formations at cavities and obstacles at pipe walls in water distribution mains.

The transport and deposition of particulates, chemical species diffusion, and nutrient retention for bioorganism constituents of surface films have been identified as dependent on flow conditions.

BUILDING MATERIALS

INORGANIC MATERIALS

CEMENT HYDRATION (COMPETENCE PROJECT)

Paul W. Brown, Building Materials Division, (301) 975-6708

Sponsor: National Bureau of Standards

The objective is to improve understanding of the physics and chemistry of cement hydration and the development of microstructure in pastes of Portland cements; and, to contribute to this understanding through development and validation of mathematical models based on physical and chemical mechanisms.

Because concrete could be a much more predictable material and a material capable of achieving higher levels of performance than are now achieved, investment in cement research has the potential of producing significant benefits to the construction industry and the Nation by providing the technical bases to improve the durability of concrete structures.

In the current year research will develop and demonstrate a time-temperature-composition dependent model for the hydration of cement, and outline an approach for modeling a polyphase cement system and demonstrate the approach for the C_3S-C_3A -gypsum system.

REPRESENTATION OF CONCRETE MICROSTRUCTURE

Hamlin Jennings, Building Materials Division, (301) 975-6720

Sponsor: National Bureau of Standards

The objective is to develop a format for symbolic representation of concrete microstructure.

Characterization of the microstructure of concrete provides valuable information concerning the condition and quality of concrete, as well as its physical and mechanical properties.

A symbolic scheme to represent the important microstructural features of concrete using a computer image processing system will be initiated. The emphasis will be to represent voids -- in particular, the size and distribution of entrained air voids added to provide protection against freeze-thaw damage. The representational scheme will be applied to concrete samples already subjected to freezing cycles, in order to assess how well the scheme correlates with freeze-thaw damage.

INFLUENCE OF PORE SOLUTION CHEMISTRY ON ALKALI-SILICA REACTION

Leslie Struble, Building Materials Division, (301) 975-6715

Sponsor: National Bureau of Standards

The objective is to study the chemical composition of the pore solution in hardened Portland cement mortar, in order to understand the role of pore solution chemistry in alkali-silica reaction.

Degradation of concrete due to alkali-silica reaction is a major concern in concrete durability. Analyses will be carried out of the relationships between the chemical compositions of the solutions, the alkali-mineralogies of the cements, and mortar bar expansions.

THE INFLUENCE OF INTERFACIAL MICROSTRUCTURE ON BONDING IN CONCRETE

Leslie Struble, Building Materials Division, (301) 975-6715

Sponsor: Department of the Air Force

The objective is to develop an improved understanding of the relationship between the microstructure of hydrated cement paste at its interface with other concrete constituents and the strength of interfacial bonds.

The bonds that form between cement paste and each of the other constituents are widely considered to be very important to concrete strength and durability. At its interface with aggregate, and probably with other concrete constituents, the microstructure of hydrated cement paste is known to be different than in the bulk paste. It is not understood, however, how this interface affects the fracture properties of the composite, and thus the strength of concrete.

The principal technique for microstructure examinations will be scanning electron microscopy, using a backscattered electron detector to examine specimens that have been impregnated with epoxy and polished.

QUANTITATIVE X-RAY DIFFRACTION ANALYSIS OF PORTLAND CEMENT CLINKER

Leslie Struble, Building Materials Division, (301) 975-6715

Sponsor: National Bureau of Standards

The objective is to develop the capability to determine the proportions of each major phase in cement clinker using quantitative X-ray diffraction analysis, and to apply it to analysis of a set of clinkers that are to become Standard Reference Materials.

The ability to determine the quantitative phase composition of cement and clinker is important both in concrete research and in the manufacture of Portland cement.

ULTRA-HIGH STRENGTH CONCRETE

Hamlin M. Jennings, Building Materials Division, (301) 975-6720

Sponsor: Department of the Air Force

The objectives are to apply material science concepts in demonstrating the feasibility of developing ultra-high strength concrete (compressive strength greater than 30,000 psi (210 MN/m^2)), and to advance the scientific knowledge of the factors controlling the mechanical properties and the fracture properties of ultra-high strength concrete.

The feasibility of casting ultra-high strength concrete, and also of developing ultra-high strength concrete by high-pressure compaction, will be investigated.

Based on state-of-the-art knowledge, a series of high-strength concretes will be designed and fabricated and the factors limiting their strength will be identified by carrying out failure analysis of tested specimens. The failure analyses investigations will involve microstructural examinations of fractured concrete to identify the source of crack initiation and propagation paths. In addition, mathematical modeling of the effect of the properties of concrete constituents on the composite behavior and fracture of ultra-high strength concrete will be performed.

PERFORMANCE REQUIREMENTS, TESTS, AND CRITERIA FOR MATERIALS USED TO REPAIR PORTLAND CEMENT CONCRETE

Lawrence I. Knab, Building Materials Division, (301) 975-6712

Sponsor: U.S. Army Corps of Engineers

The objective is to determine preliminary performance criteria for selecting materials to repair concrete structures which have cracks, spalls, and scaling.

The performance requirements (e.g., resist shear forces) and associated material properties (e.g., shear strength) for the important in-service degradation factors, such as mechanical stress, temperature and temperature fluctuations, moisture, aggressive chemicals, ultraviolet light, and time of exposure will be identified. Performance tests and criteria will then be determined for appropriate performance requirement-degradation factor combinations.

EVALUATION OF THE STRENGTH OF THE BOND BETWEEN REPAIR MATERIALS AND EXISTING CONCRETE

Lawrence I. Knab, Building Materials Division, (301) 975-6712

Sponsor: Tri-Services Materials Committee

The objective is to develop a procedure for evaluating the strength of the bond between repair materials and existing concrete.

The strength of the bond between a repair material and its existing concrete substrate is a major factor in the effective repair of existing concrete structures. There is a need for a repeatable test to evaluate the bond.

The tensile test method developed in FY 85 will be modified by increasing the specimen diameter and grip capacity. Several repair materials, surface preparations, and existing concrete substrates will be included in the statistically designed study.

EXPERT SYSTEM FOR DURABLE CONCRETE

James R. Clifton, Building Materials Division, (301) 975-6707

Sponsor: National Bureau of Standards

The objective is to develop a prototype expert system which systematically provides recommendations on the selection of constituents for concrete subjected to a broad range of service conditions.

The ACI Guide to Durable Concrete has been selected as the prime source for the knowledge base of the expert system. Other documented information sources also may be used in later developments of the expert system (e.g., guidelines on corrosion mitigation developed by ACI Committee 222 on Corrosion of Metals in Concrete). A subcommittee has been established within ACI Committee 201 to critique the expert system and to give recommendations on improvements to the knowledge base.

EVALUATION OF STONE PRESERVATIVES

James R. Clifton, Building Materials Division, (301) 975-6707

Sponsor: Architect of the Capitol

The objective is to determine the effect of possible preservatives on the service life of the sandstone and protective coatings and to develop performance criteria for the selection of preservatives.

This work will include determining the effects of possible preservatives on the microstructure, mechanical properties, permeability, and durability of the stone. Other studies include measurement of the adhesion of protective coatings to the sandstone treated with preservatives and the depth of penetration of the sealant into the sandstone. The long-term effects of sealants on the durability of the stone and protective coating will be evaluated using accelerated durability tests, which simulate the environmental conditions the stone is exposed to in service.

The factors controlling the performance of stone preservatives will be identified and, based on the knowledge, performance criteria will be developed.

DEHYDRATION AND REHYDRATION OF INORGANIC SALTS FOR PASSIVE SOLAR ENERGY STORAGE

Leslie Struble, Building Materials Division, (301) 975-6715

Sponsor: Department of Energy

The objective is to assess the long-term ability of ettringite dehydration to store thermal energy.

The reversibility of the reaction will be studied through repeated cycles of dehydration and rehydration, and the data examined for any evidence of chemical or physical degradation. The research will improve our understanding of what material parameters affect the long-term performance of hydrated inorganic salts for energy storage.

DURABILITY AND PERFORMANCE EVALUATION OF LOW-EMITTANCE GLAZING MATERIALS

David Waksman, Building Materials Division, (301) 975-6707

Sponsor: Department of Energy

The objective is to develop and evaluate methods for determining the performance of low-emittance glazing materials. The several techniques for measuring the emittance of glazings can give significantly different results. The first phase of the project is to evaluate the techniques, and the second is to provide a consistent test method. In FY 86, at the request of the sponsor, the work is to be redirected to support the International Energy Agency (IEA) Task X on Materials Performance. Summaries describing test methods relevant to materials used in solar heating and cooling systems will be prepared for submission to the Task X Committee.

T/S TECHNICAL AND SCIENTIFIC SUPPORT

Robert G. Mathey, Building Materials Division, (301) 975-6709

Sponsor: Department of Defense (Tri-Service)

The objective is to provide technical and scientific support services on the performance of building materials and systems as required by the Tri-Services. The work includes management of the Tri-Service Building Materials Investigational Program at NBS, and carrying out laboratory tests and evaluations in the solution of building problems as well as field investigations. Recommendations will be made with regard to the selection of materials and systems and their application and performance.

ORGANIC MATERIALS

DEGRADATION OF ORGANIC PROTECTIVE COATINGS

Tinh Nguyen, Building Materials Division, (301) 975-6718
Mary E. McKnight, Building Materials Division, (301) 975-6714

Sponsor: National Bureau of Standards

The objective is to (1) identify mechanisms leading to blister formation and corrosion, and (2) develop improved methods for characterizing coating reactions and properties that control degradation at the steel/coating interface.

Research in FY 86 will concentrate on (1) characterizing and quantifying chemical changes at the steel/coating interface of high performance coatings at 80 percent RH and 70 and 90 C, (2) proposing degradation mechanisms for those materials, and (3) characterizing coating reactions and properties that control interfacial degradation.

ORGANIC COATINGS

Mary E. McKnight, Building Materials Division, (301) 975-6714

Sponsor: Tri-Services Coatings Committee

The objectives are to (1) stay abreast of problems in selection, specification, and use of coatings by interacting with the users, manufacturers, and applicators of coatings; (2) develop improved test and evaluation methods for predicting the service life of protective coatings as determined by these interactions; and (3) implement results of the research of the Organic Materials Group by transferring information to the coating users.

Current work includes contributions to the ASTM standard for interior flat latex paint and to the Tri-Services Paint and Protective Coatings Manual.

COATING MAINTENANCE OF FACTORY COATED METAL SIDING AND ROOFS

Robert G. Mathey, Building Materials Division, (301) 975-6709
Mary E. McKnight, Building Materials Division, (301) 975-6714

Sponsor: Air Force Engineering and Services Center

The objective is to develop guidelines for the maintenance of metal siding and roofing.

Laboratory and field test methods will be selected and candidate maintenance coating systems, along with application methods, will be tested and evaluated. Surface preparation procedures will also be evaluated taking into consideration the type and condition of the substrate. Using the initial results of the laboratory and field tests and information from the the first phase of the study, interim criteria will be prepared for recoating metal siding and roofing.

IMPROVED CHARACTERIZATION OF COATING SYSTEM PERFORMANCE

Mary E. McKnight, Building Materials Division, (301) 975-6714
Jonathan W. Martin, Building Materials Division, (301) 975-6717

Sponsor: Naval Civil Engineering Laboratory

The objective is to develop infrared thermographic characterization of corroded and blistered coatings on steel panels.

Alternative methods of heating and recording of data will be investigated to optimize characterization of blisters and corrosion of organic coating systems on steel.

A computer-based imaging system will be studied to seek quantitative and sensitive methods for characterizing the performance of coating systems.

QUANTITATIVE CHARACTERIZATION OF THE SURFACE PROPERTIES OF BUILDING MATERIALS VIA COMPUTER IMAGE PROCESSING

Jonathan W. Martin, Building Materials Division, (301) 975-6717
Mary E. McKnight, Building Materials Division, (301) 975-6714

Sponsor: National Bureau of Standards

The purpose of this study is to advance the technology of surface characterization of building materials using computer image processing and photon emission properties of the profile elements.

Phase 1, to be carried out in FY 86, will consist of (1) developing a methodology for utilizing computer image processing to characterize the surface of materials, and (2) demonstrating the use of the methodology for profiling the surface of blasted steel.

PROBABILISTIC STUDY OF SINGLE-PLY ROOFING MEMBRANES

Jonathan W. Martin, Building Materials Division, (301) 975-6717

Sponsor: National Bureau of Standards

The purpose of this study is to develop probabilistic methods for predicting the service-lives of single-ply roofing seams.

At the elemental level, the chemical and photolytic degradation processes occurring in the membrane, insulation, and seam adhesive will be studied when each element is exposed to thermal, moisture, and photolytic environments (or combinations of these environments). This degradation data, along with the environmental stress data, will be used in modeling the mechanisms of seam failures in predicting, using appropriate probabilistic models, the static fatigue lives of single-ply adhesive joints subjected to both mechanical and thermal environments, and in studying how the magnitude of the mechanical stress in the adhesive joint changes with temperature and aging of the seam.

FACTORS AFFECTING INITIAL BOND OF SEAMS IN SINGLE-PLY RUBBER MEMBRANES

Walter J. Rossiter, Building Materials Division, (301) 975-6719

Sponsor: Department of Defense

The objective is to determine the effect of application conditions on the initial bond strength of adhesive-bonded seams in single-ply rubber membranes.

The basis of the test for assessing seam quality will be a peel test, since limited unpublished data have indicated that the bond strength (in peel) of seams prepared from uncleansed rubber sheets is significantly reduced from that of seams prepared using properly cleaned sheets.

The key application parameters considered to affect seam quality are surface cleanliness (or contamination), applied pressure, and temperature.

PERFORMANCE CRITERIA FOR BITUMINOUS MEMBRANE ROOFING

Walter J. Rossiter, Building Materials Division, (301) 975-6719

Sponsor: E.I. duPont de Nemours & Company

The objectives are to assess performance criteria for bituminous membrane roofing and to revise the preliminary performance criteria for which a technical basis exists for revision.

Information will be reviewed on major mechanisms of failure, analytical and laboratory studies will be conducted and appropriate criteria proposed.

MATERIALS REFERENCE LABORATORIES

CEMENT AND CONCRETE REFERENCE LABORATORY (CCRL)

James H. Pielert, Building Materials Division, (301) 975-6704

Sponsors: ASTM and U.S. Army Corps of Engineers

The objective is to promote improvement in the quality of testing of cement, concrete and aggregates in the Nation's testing laboratories through test method assessment and development, support to the development of national standards, and support to quality control and quality assurance programs.

Almost 600 laboratories are inspected every two to two and a half years to assess the quality of testing according to ASTM methods and specifications. Over 2000 proficiency test samples of cements and concretes are distributed annually to obtain information on laboratory performance. Technical studies are conducted in cooperation with other NBS units and organizations outside NBS to aid understanding of the properties and performance of construction materials.

AASHTO MATERIALS REFERENCE LABORATORY (AMRL)

James H. Pielert, Building Materials Division, (301) 975-6704

Sponsor: American Association of State Highway and Transportation Officials

The objective is to promote improvements in the quality of testing of soils, aggregates and asphaltic materials and mixtures in the Nation's testing laboratories through test method assessment and development, support to the development of national standards, and support to quality control and quality assurance programs.

Almost 100 laboratories are inspected every one and a half to two years to assess the quality of testing according to AASHTO methods and specifications. Over 2000 proficiency test samples of soils, aggregates and asphalts are distributed annually to obtain information on laboratory performance. Technical studies are conducted in cooperation with other NBS units and organizations outside NBS to aid understanding of the properties and performance of construction materials.

CALIBRATION OF PAVEMENT ROUGHNESS MEASURING DEVICES

James H. Pielert, Building Materials Division, (301) 921-6704

Sponsor: Federal Highway Administration

The objective is to develop and demonstrate procedures that can serve as the basis for field calibration of highway pavement roughness measuring devices. Analytical, laboratory, and field studies will be conducted to develop and verify calibration procedures.

RESEARCH INFORMATION

CBT INFORMATION MANAGEMENT

Noel J. Raufaste, Structures Division, (301) 975-5905
Lawrence J. Kaetzel, Center Headquarters, (301) 975-5912

Sponsor: National Bureau of Standards

The objective is to develop and maintain an overall framework for information delivery and information management taking advantage of the increasing CBT computing capability.

CBT's findings are disseminated by technical reports, presentations, and by staff serving on voluntary standards committees. These delivery methods contribute to improved building standards and are an important element in CBT's overall framework for technology transfer. This project focuses on information management; e.g., assessing user needs (building community and CBT staff), developing methods to better communicate information, and participating in international building organizations and domestic professional organizations.

ECONOMIC METHODS FOR BUILDING STANDARDS

Harold E. Marshall, Center for Applied Mathematics, (301) 975-6131

Sponsor: National Bureau of Standards

The objective is to develop guidelines and standards for evaluating alternative building technologies using consistent economic methods.

Economic methods and supporting analyses will be especially developed for application to building problems. A special publication on handling risk and uncertainty in the economic evaluation of buildings will be completed for use by ASTM in the development of a standard.

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See Instructions)		1. PUBLICATION OR REPORT NO. NBSIR-86-3490	2. Performing Organ. Report No.	3. Publication Date DECEMBER 1986
4. TITLE AND SUBTITLE Building Technology Project Summaries 1986				
5. AUTHOR(S) Richard N. Wright				
6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions) NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON 20560-2000 Gaithersburg, MD 20899			7. Contract/Grant No.	8. Type of Report & Period Covered
9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP) National Bureau of Standards Department of Commerce Gaithersburg, MD 20899				
10. SUPPLEMENTARY NOTES <input type="checkbox"/> Document describes a computer program; SF-185, FIPS Software Summary, is attached.				
11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here) The Center for Building Technology (CBT) of the National Bureau of Standards (NBS) is the national building research laboratory. It works cooperatively with other organizations, private and public, to improve building practices. It conducts laboratory, field, and analytical research. It develops technologies to predict, measure, and test the performance of building materials, components, systems, and practices. This knowledge is required for responsible and cost-effective decisions in the building process and cannot be obtained through proprietary research and development. CBT provides technologies needed by the building community to achieve the benefits of advanced computation and automation. CBT does not promulgate building standards or regulations, but its technologies are widely used in the building industry and adopted by governmental and private organizations that have standards and codes responsibilities. This report summarizes the projects underway in the Center during 1986.				
12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons) Building research; building technology; criteria; measurement and test methods; performance criteria; project summaries; standards; technical bases				
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